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SUPERFUND RECORDS

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**FINAL  
TECHNICAL MEMORANDUM  
WATER QUALITY OF GROUNDWATER  
IN THE GALENA AREA  
CHEROKEE COUNTY SITE**

**102-7.37/W68540  
June 1987**





Engineers  
Planners  
Economists  
Scientists

June 5, 1987

W65541.ED

Ms. Alice Fuerst  
U.S. Environmental Protection  
Agency, Region VII  
726 Minnesota Avenue  
Kansas City, Kansas 66101

Dear Ms. Fuerst:

Enclosed are 24 copies of the Final Technical Memorandum on the groundwater system at the Galena subsite. Following your approval, we anticipate you will forward this memorandum to KDHE. We will be available to respond to questions or meet with EPA and KDHE at your request.

Please call if you require more copies or have any questions.

Sincerely,

A handwritten signature in cursive script that reads "Richard Moos".

Richard Moos  
SM, Cherokee County Site

DE/CC5/056/tcl

Enclosure

cc: Gale Wright/EPA Region VII, KCK  
Mike Thompson, RM/CH2M HILL, DEN  
Bill Bluck, RLT/CH2M HILL, DEN  
Dick Glanzman/CH2M HILL, DEN  
Neil Geitner/CH2M HILL, DEN  
Bob Ogg, AZPM-Operations/CH2M HILL, WDC



TECHNICAL MEMORANDUM  
WATER QUALITY OF GROUNDWATER IN THE GALENA AREA  
CHEROKEE COUNTY SITE

INTRODUCTION AND PURPOSE

The Environmental Protection Agency has completed the first phase of the remedial investigation (RI) on the Galena subsite for the Cherokee Country RI/FS. This phase of the investigation has identified concentrations of heavy metals in groundwater and surface water that exceed standards and criteria for the protection of public health and the environment. The purpose of this technical memorandum is to briefly summarize the Phase I RI findings regarding heavy metal contaminant exceedances of health and environment standards and criteria, and discuss some of the implications of this heavy metal contamination at the site.

As a result of these exceedances, the EPA is developing a work plan to select and evaluate remedial alternatives, including estimated costs, for the remediation of the Galena subsite groundwater system. The goals and objectives of this work need further definition, particularly the degree of cleanup of the shallow aquifer which is impacted by past mining activities. This work involves not only technical issues but also institutional and legal issues that will strongly impact both the alternatives and the cost. This technical memorandum provides a data base and information so that EPA, KDHE, and the Corps of Engineers can continue discussing the technical, legal, and institutional issues and provide better definition for the project goals and objectives.

BACKGROUND

Groundwater at the Cherokee Superfund Site

The geologic and hydrologic data for the site are closely tied to the mining in the Tri-State District--an area that produced lead and zinc from approximately 1870 through the 1970's. The first producing areas include Galena, Kansas, and Joplin, Missouri (Figure 1). Lead production in the Galena, Kansas, area peaked prior to 1900 and ended before 1920. Mining in the Picher area of Kansas and Oklahoma peaked in the mid-1920's and has only recently declined to essentially no production. The early years in the lead and zinc mining involved dewatering the ore bodies, mining and processing the ore, and producing groundwater for both processing the ore and for the miners and their families.

Mining caused changes in the hydrology of the areas by creating extensive new fractures and removing economically



recoverable metals. The process created zones of high permeability and large, commonly connected, openings (McCauley et al., 1983) that greatly increased the amount of water in storage in the shallow bedrock (0-300 feet). The surface is penetrated by closely spaced shafts providing large conduits from the surface into the groundwater storage (Figure 2). Large areas of the surface surrounding the mine shafts and the processing areas are covered with coarse-grained material (mine waste, tailings, chat piles) that increase the amount of recharge to the groundwater system by impeding runoff, both by retaining the infiltrating rainfall in its pore space and by forming a mosaic through which runoff is impeded.

The increased recharge and storage to the groundwater system are putting highly oxygenated, low total dissolved solids (TDS), rain water into direct contact with a much larger quantity (surface area) of metal-rich sulfide minerals than originally present in the premining condition. These minerals oxidize creating a relatively high TDS acid solution that contains metals at concentrations that may be hazardous to human health.

In the case of lead and zinc production at Galena, the price of zinc was too low during the early production so that much of the mineral sphalerite ( $ZnS$ ) was left behind in the subsurface and in the mine wastes at the surface. Sphalerite in the Tri-State District contains between 0.44 and 0.73 percent or 4,400 and 7,300 parts per million cadmium. Pyrite and marcasite ( $FeS_2$ ) are also left behind with the sphalerite and probably create most of the acid and iron that goes into the solution. This solution attacks the sphalerite putting both zinc and cadmium into solution.

The amount of sphalerite and cadmium left behind by the early mining at Galena can be estimated by comparing the ratio of zinc to lead produced at Galena with the ratio produced at large mining areas during time periods when zinc was economically recoverable. Five areas had production in excess of 1 million tons of lead and zinc concentrates (galena and sphalerite, respectively) with an average zinc to lead ratio of 6.06 compared with the Galena area ratio (the lowest) of 5.71. Multiplying these out and subtracting the produced sphalerite from the calculated sphalerite gives the estimated amount of sphalerite left behind at Galena of 72,000 tons. This is probably a conservative estimate because the 72,000 tons is the ore grade production left behind not the total sphalerite in the bedrock. The estimated 72,000 tons of sphalerite contain approximately 58 percent zinc and at least 0.44 percent cadmium; therefore, approximately 42,000 tons of zinc and 320 tons of cadmium may be exposed to surface and groundwater in the Galena area. One unknown





is the amount of mine wastes that have been removed from the Galena area for reprocessing, construction material, etc.

The source and transport of the cadmium in the shallow groundwater system are illustrated in Figure 2. Nine of the ten private wells completed in the shallow bedrock aquifer containing as much as five or more ppb cadmium are located downgradient of the abandoned mine lands. The cadmium in the groundwater is a result of the oxidation of sphalerite in the mine wastes and mine workings moving downgradient along fractures in the bedrock.

#### METAL SOURCES

The direct interconnection between the ground and surface water systems plays an important role in how metal contaminants influence the quality of these water systems, not only in the Galena area also but within the Cherokee County region. The surface water is both a source of recharge to, and discharge from, the groundwater. In general, the recharge is good quality water but the discharge from the groundwater back to the surface water is of poor quality because heavy metals contamination is being carried to the surface waters.

Heavy metals, such as iron, cadmium, manganese, nickel, and zinc, are dissolved from the mine wastes on the surface, the sulfide minerals exposed in the mine workings, and the sub-economic sulfide minerals in the periphery of the mine workings. Rainfall and surface water infiltrate into the shallow groundwater system through mine waste piles on the surface and surface soils. Most of the mine wastes at Galena contain significant amounts of the zinc sulfide mineral, sphalerite, in addition to the iron sulfide minerals, pyrite, and marcasite. However, a few of the mine waste piles at the Galena subsite are chat piles similar to those in the Tar Creek area in which the sulfides have been removed. From the amount of sphalerite seen in the mine waste piles near Galena it might also be implied that subsurface mining left sphalerite as well as pyrite and marcasite in the subsite mine workings. The mining activities created fractures that potentially connect individual mine workings and also connect to the natural subsurface fracture system supplying groundwater to private wells and eventually to the surface water. The fractures may also connect the mine workings to the deep Roubidoux aquifer. However, based on the data presently available, this does not appear to be happening to any significant degree at the Galena subsite.

Sulfuric acid, the principal product resulting from the oxidation of sulfide minerals, is creating acid mine drainage at the subsite. The iron sulfide minerals, because of their abundance and weathering characteristics, are the primary minerals in the generation of sulfuric acid and the red,



yellow, and brown colors characteristic of acid mine drainage. Iron, primarily responsible for the color, can also impart both odor and taste to water as water flows over or through areas with oxidizing sulfides. The acidic water from the chemical oxidation process attacks other sulfide minerals and the limestone/dolomite rocks surrounding the sulfides. Acid attack on the sphalerite present in Cherokee County releases zinc, cadmium, and more sulfate. Acid attack on limestone and dolomite increases the calcium concentration in the water with either host rock. Magnesium concentration also increases with dolomite decomposition. Carbon dioxide gas is also generated, some of which goes into solution as bicarbonate ions, and some is driven off as a gas. Attack on the limestone and dolomite increases the fracture volume and thereby increases the flow of potentially heavy-metal-laden acid mine water to private wells, surface water, and perhaps the deep aquifer in the Galena area.

#### PHASE I REMEDIAL INVESTIGATION

Water samples collected during the first phase of the remedial investigation at the Galena subsite were analyzed for 27 metals. These data were compared to standards and criteria for fourteen heavy metals that are established by the Safe Drinking Water Act (40 CFR 141) and the Clean Water Act (40 CFR 131) for the protection of public health and the environment. The data were from water samples from 15 mine shafts and 110 private wells tested for dissolved metals and 16 mine shafts and 129 private wells tested for total metals concentration. The dissolved metals samples were filtered in the field, and the total metal samples were not. Both types of samples were acidified. Tables 2, 3, 4, and 5 compare the Table 1 standard and criteria values with both total and dissolved metals concentrations in mine shaft and private well samples in the Galena area.

#### PUBLIC HEALTH WATER QUALITY EXCEEDANCES

For this technical memorandum, the exceedance of the standards and criteria was calculated by dividing each sample concentration value for a metal by the standard and/or criteria. With this method, values greater than one define an exceedance. Table 2 summarizes the comparison between Galena subsite water quality and the standards and criteria for the protection of public health. Table 3 summarizes the comparison of total and dissolved heavy metal results with the standards and criteria for protection of the environment.

The nine heavy metals that exceeded public health water quality standards and criteria are listed in Table 2 in the relative order the metals exceeded standards and criteria for samples from private wells. For example, total iron levels in wells that exceeded the secondary drinking water standard



were 12.9 times higher than the standard, on the average. Zinc concentrations, however, were only 1.6 times the standard. The mine shaft and private well order of exceedance is the same, with the exception of lead, and to some extent zinc. The higher lead levels found in the mine shafts may be due to dissolution in the mine workings (pillars, dispersed minerals, etc.), but the levels may also be attributable to a lack of mobility of the lead ion. Zinc is probably more abundant in the mine workings than in the periphery of the mine workings. The greater zinc exceedances in mine shafts therefore are due to its abundance in the mine workings and potentially some precipitation and adsorption.

Iron has a secondary drinking water standard. It is one of the most noticeable metal contaminants (without chemical analysis) because of staining, taste, and odor at near part per million concentrations. The iron sulfides commonly form a dispersed halo around ore deposits which causes a very large iron anomaly in groundwater. The Galena subsite is a good example of the widespread iron problem. Private well total and dissolved iron, and mine shaft total iron have essentially the same exceedance values. Mine shaft dissolved iron is lower probably because of oxygen dispersing into the mine shaft water from the surface causes much of the iron to precipitate.

Cadmium has a primary drinking water standard. The Galena subsite groundwater exceedances for cadmium are essentially the same for samples taken from both mine shafts and private wells. The total cadmium results from private wells are unexplainably lower than the dissolved cadmium exceedances. Cadmium and manganese frequently travel together having similar positions in the periphery of ore deposits and having similar mobilities. Manganese, like iron, has a secondary drinking water standard and can also stain and cause both taste and odor problems in drinking water.

Nickel and silver have human health criteria values. Nickel analytical results show approximately twice the exceedance in private wells as in mine shaft groundwater samples at the Galena subsite. The nickel values observed in private wells may be a result of acid attack on the limestone and dolomites. Nickel is commonly enriched in calcium-rich rocks, particularly carbonates. Nickel is also a highly mobile ion and is frequently enriched in rocks peripheral to ore deposits.

There are only one dissolved and three total silver exceedances. There were no exceedances for silver in the mine shaft groundwater. The implication is that silver is either largely enriched in peripheral rocks or it is contributed by private well construction components or pumps.



Chromium and selenium results, like those for silver, show only a few low exceedance values that occur only in the private well samples. The chromium was determined as total chromium and compared to the chromium VI standard as a worst case possibility. Selenium is very close to the standard with one total and two dissolved selenium concentrations exceeding the 10 microgram per liter standard.

#### ENVIRONMENTAL WATER QUALITY EXCEEDANCES

Comparing groundwater quality to the water quality criteria for protection of aquatic life is pertinent because the groundwater in the Galena area forms the base flow in Short Creek and other tributaries, and therefore eventually comprises a significant proportion of the Spring River flow in the site. In addition to the natural surface/groundwater connection, mining activities have created large underground conduits that are hydraulically connected to the surface water system. The first phase of the remedial investigation on the Galena subsite led to the conclusion that there is significant inflow of poor quality shallow groundwater to the surface streams near and adjacent to the mining zone.

The Clean Water Act established water quality criteria for aquatic life. Table 3 lists the metal parameters in the mine shafts and private wells that exceed the chronic and acute water quality criteria established by the Act. In both the chronic (essentially continuous hazard level to aquatic life) and the acute (time dependent hazard level to aquatic life) tables, the metal parameters are listed in order of the mine shaft exceedance values. These values reflect a potentially undiluted threat to aquatic life from shallow groundwater moving through the Galena area subsurface strata and mine workings, to become point and nonpoint discharges to Short and Shoal Creeks.

Eight metals in shallow groundwater samples from the Galena subsite exceeded the chronic ambient water criteria for aquatic life. Zinc, lead, and cadmium values in mine shaft groundwater exceeded their respective standards by 422, 92, and 95 times. In effect, it would take 422 water volumes at essentially zero zinc concentration to dilute the dissolved zinc in mine shaft water to compliance with the aquatic life criteria. The zinc in private well water would require on approximately 40-fold dilution to be in compliance. Surface water quality investigations are underway to estimate the amount of shallow groundwater and the groundwater quality discharging into Short Creek. Rainfall through the surface mine waste will also contribute to the surface water load of zinc and cadmium.

A total of seven metals in the shallow groundwater of the Galena subsite exceeded standards for acute ambient water





quality criteria. Zinc, cadmium, and lead in mine shaft groundwater had exceedances of 62, 26.8, and 11.9. Private well groundwater had a high cadmium exceedance (17.4) with the exceedance of iron approximately equal to the zinc exceedance.

### REMEDIAL ALTERNATIVES

The emphasis for evaluation of remedial alternatives under the Superfund Amendments and Reauthorization Act (SARA) of 1986 is on implementation of long-term remedies for the release or threatened release of hazardous substances. The alternatives must meet standards under any federal or State of Kansas environmental law that apply to the hazardous substances being addressed or are relevant and appropriate under the circumstances. The degree of cleanup is to be defined by the EPA and the State of Kansas through evaluation of promulgated standards and criteria. For example, application of the Federal Safe Drinking Water and Clean Water Acts criteria shows an exceedance of eight metal contaminants in private wells. These metal analysis results also exceed Kansas action levels listed in the unpromulgated State Groundwater Contaminant Cleanup Target Concentrations which are equal to or lower than the federal standards and criteria. For instance, the Kansas Action level for cadmium is 5 µg/l while 10 µg/l is the federal primary drinking water standard. Similar differences occur for other constituents in both the public health and the environmental standards.

Potential remedial alternatives must be consistent with the National Contingency Plan (NCP), consider alternative treatment technology, utilize resource recovery where practicable, and be cost effective. The general remedial alternative categories preliminarily identified for groundwater in the Galena area include:

1. No Action
2. Administrative Action
3. Alternative Water Supply
4. Collect and treat the shallow groundwater
5. Remove and/or reduce source, recharge, and discharge

The No Action and Administrative Action categories will probably both be "minimal" cost alternatives. Both allow shallow groundwater to continue contributing metals exceeding public health and environmental standards to private wells and surface water. Administrative Action could include prohibiting development of new shallow groundwater wells. The EPA has equipped some private wells with a filter system to reduce the metals in drinking water. An alternate water supply for all private wells is a potential long-term remedial alternative. This alternative, however, would lower the water level of the deep aquifer if deep groundwater is used (current



municipal and water district source) and potentially allow the shallow groundwater to contaminate the deep aquifer. Another option for remediation may be to pump and treat the shallow groundwater using it for the alternative water supply. The surface water resource is also an alternative water supply. The final general category of remedial alternatives, (remove and/or reduce the source, recharge and discharge) can involve one or a combination of many activities. Some of those might include plugging the mine shafts, processing sphalerite rich mine wastes (resource recovery, source control), recontouring the existing surface with clean chat to reestablish surface drainage and diverting surface drainage from the mined zone.

To get to the point when the above general remedial alternatives and others can be evaluated, additional Galena subsite and Cherokee County field data are needed. Field activities are being undertaken to gain information that will help the project team more accurately compare remedial alternatives for the site and Galena subsite.

Data obtained during the upcoming field work and information presently available will be used to complete an operable unit feasibility study (OUFS) for the Galena subsite groundwater. The OUFS process will screen, develop and evaluate remedial alternatives, including estimated costs, specifically for the goals and objectives to be jointly established by the EPA and the State of Kansas for the Galena Subsite groundwater system. Development of the project goals and objectives and determining the level of cleanup must consider the applicable or relevant and appropriate requirements (ARAR's) related to action being evaluated for OUFS remedial alternatives.

#### POTENTIAL COSTS

It is not possible to estimate the costs of the remedial actions at Galena without specific goals and objectives, and criteria for the degree of cleanup of the shallow groundwater system. These goals, objectives, and criteria will be determined in the near future, when EPA begins the operable unit feasibility study for the Galena subsite groundwater system. In the meantime, some idea of potential cost impacts can be gained by a review of remedial alternative costs at two other Superfund sites where acid mine drainage (AMD) is the main problem. Emphasis is placed on water treatment alternatives, because restoration of the shallow groundwater quality at Galena would probably require either treatment or contaminant source removal. The two sites are Tar Creek in Oklahoma and the Iron Mountain Mine site in California. Cost estimates from these two sites are not directly applicable to the Galena subsite because of site specific differences, and estimates for Galena may be plus or minus orders



of magnitude from the Tar Creek and Iron Mountain cost estimates.

A lime/limestone neutralization process was the proposed AMD treatment alternative at the Iron Mountain Mine Site near Redding, California. Three different treatment alternatives were evaluated, but all three used the neutralization treatment process. They differed primarily in the amount of water treated. The treatment process train included addition of limestone to raise the pH to 4, a first-stage settling lagoon, addition of lime to raise the pH to 8.5, addition of air to oxidize (precipitate) iron, a heavy solids separator, and a second-stage solids lagoon for sludge removal.

The smallest of the three treatment systems would treat 4,000 gpm of AMD and was expected to remove up to 86 percent of the copper and 93 percent of the zinc and cadmium being released via AMD from the Iron Mountain Site. This 4,000 gpm system had an estimated annual O&M cost of \$1 million and would cost \$21 million to design and construct (Table 8). Disposal of the sludge would be a major cost item in addition to other O&M costs, assuming the sludge would have to be disposed at a RCRA facility.

The largest of the three treatment systems would handle 110,000 gpm, have an estimated O&M cost of \$2.3 million per year and cost \$114 million to design and construct (Table 8).

The Iron Mountain Mine site costs may be different from Galena because:

- o The form of mineralization and mining methods were different.
- o The host rock for the sulfide ore body is different.
- o The physical, socioeconomic, and political environments were different.
- o The Iron Mountain Mine FS and ROD were completed prior to SARA.

The Tar Creek site in Oklahoma differs from the Galena sub-site in Kansas, even though both mining areas are within the Tri-State Mining District. The Galena area was mined much earlier, when zinc was subeconomic (it cost more to produce the zinc ore than it was worth at that time). Therefore, some of the sphalerite was likely left in the ground, and an undetermined amount was also left in the surface mine wastes. Mining activities and processing techniques were directed at producing lead rather than zinc. Ore processing methods were also different at the two sites. The earlier Galena



methods were less effective and left more residual ore in the mine wastes. Also, the larger mines at Tar Creek resulted in larger chat piles. In later years most of these chat piles in the Tar Creek area were reprocessed to recover more of the lead and zinc. These two sites also have some important geologic and geohydrologic differences. The above factors are expected to have a significant influence on remedial action costs.

The Tar Creek feasibility study estimated costs for treating water in the deep Roubidoux aquifer, and also treating the groundwater (shallow aquifer) discharges coming from the mines. The estimated treatment costs for the Roubidoux water system are shown in Table 9, assuming treatment systems were developed for 21 different wells with a total capacity of slightly less than 10 million gallons of water per day. The fixed costs for engineering and constructing these facilities was estimated at \$11 million. The annual O&M costs were estimated at about 3 million per year, plus \$2.7 million per year for sludge management and disposal. The treatment process in this case was designed to provide drinking water meeting both primary and secondary drinking water standards.

The treatment alternative for groundwater discharges (acid mine drainage) at the Tar Creek site was designed to treat 500,000 gallons per day (gpd). The treated effluent, however, would only meet the maximum allowable Oklahoma standards for discharges of wastewater into intermittent streams or storm sewers. The quality of the effluent, in several cases (metals), would not meet drinking water criteria or federal ambient water quality criteria for protection of aquatic life. For example, the designed treatment process had zinc concentrations in the effluent up to 1,000 µg/liter and cadmium concentration up to 30 µg/liter (Tar Creek, 1983).

The mine discharge treatment facility was based on a lime neutralization process, included equalization ponds to hold 1.5 million gallons, and would utilize package plants that would be purchased and assembled either at the factory or in the field. The engineering, construction, and land purchase costs were estimated to total about \$1 million. Annual O&M costs were estimated at \$330,000, excluding sludge management and disposal. The estimated costs for this treatment facility at Tar Creek will likely be orders of magnitude less than a system designed to meet ambient water quality criteria for the protection of aquatic life.

## CONCLUSIONS

The shallow groundwater at Galena contains heavy metal contaminants that exceed, in some cases, by a significant amount, drinking water standards and water quality criteria for human health and aquatic life. Mine wastes are a source of heavy metals to the surface waters and groundwaters.





The shallow groundwater and surface water systems are so strongly interconnected they are virtually one system.

Additional field data will be obtained for use in a Galena subsite groundwater OUFS to screen, develop, and evaluate remedial alternatives specifically designed for project goals and objectives. Costs for each remedial alternative can only be reasonably estimated as an integral part of the OUFS process. Remedial alternatives must address state and federal applicable or relevant and appropriate requirements (ARAR's). The degree of cleanup and ARAR's for the shallow groundwater system at Galena needs to be fully defined by EPA Region VII and the state of Kansas in the work plan stages to complete the OUFS.

### Reference

McCauley, J. R., Brady, L. L., and Wilson, F. W. A Study of Stability Problems and Hazard Evaluation of the Kansas Portion of the Tri-State Mining Areas, U.S. Department of the Interior, Bureau of Mines Contract J0100131.

Tar Creek Task Force, 1983. Tar Creek Feasibility Investigation: Task II.4.A, Evaluation of Treatment Alternatives. Prepared by Oklahoma State University, August 1983.



Table 1

STANDARDS AND CRITERIA USED FOR METAL PARAMETER COMPARISON  
FOR GALENA SUBSITE GROUNDWATER SAMPLE RESULTS

Metal Parameter	Drinking Water Standards <sup>a</sup>	Water Quality Criteria for Human Health <sup>b</sup>	Ambient Water Quality Criteria for Aquatic Life <sup>b</sup>	
	Current MCL (µg/l)	Standard (µg/l)	Chronic (µg/l)	Acute (µg/l)
Arsenic	50	--	190	360
Beryllium	--	--	5.3	130
Cadmium	10	10	1.1	3.9
Chromium (III) <sup>c</sup>	--	179,000	210	1,700
Chromium (VI) <sup>c</sup>	50 <sup>d</sup>	50	11	16
Copper	1,000 <sup>d</sup>	1,000	12	18
Iron	300 <sup>d</sup>	--	--	1,000
Lead	50 <sup>d</sup>	50	3.2	83
Manganese	50 <sup>d</sup>	--	--	--
Mercury	2	10	0.012	2.4
Nickel	--	15.4	160	1,400
Selenium	10	10	35	260
Silver	--	50	0.12	4.1
Thallium	--	17.8	--	--
Zinc	5,000 <sup>d</sup>	5,000	47	320

<sup>a</sup> Drinking Water Standards--Safe Drinking Water Act; 40 CFR 141.

<sup>b</sup> Water Quality Criteria for Human Health and Aquatic Life--Clean Water Act; 40 CFR 131.

<sup>c</sup> Only the Chromium VI criteria are used in data comparison.

<sup>d</sup> Secondary MCL.



Table 2  
SUMMARY OF WATER SAMPLE RESULTS FROM THE GALENA SUBSITE FOR  
HEAVY METALS EXCEEDING PUBLIC HEALTH  
WATER QUALITY STANDARDS OR CRITERIA

Metal	Standard or Criteria (µg/l)	Source	Mean Metal Exceedance Values			
			Mine Shaft		Private Well	
			Total	Dissolved	Total	Dissolved
Iron	300	B	12.7	4.0	12.9	12.7
Cadmium	10	A,C	11.1	10.4	6.5	9.2
Manganese	50	B	4.9	5.1	5.1	5.7
Nickel	15.4	C	2.5	--	4.3	5.2
Silver	50	C	--	--	2.0	2.0 <sup>a</sup>
Zinc	5,000	B	4.2	4.0	1.6	1.7
Chromium (VI)	50	A,C	--	--	1.6	1.5 <sup>a</sup>
Selenium	10	A,C	--	--	1.1 <sup>a</sup>	1.4
Lead	50	A,C	15.5	16.0	4.6 <sup>a</sup>	--

<sup>a</sup> Single Sample.

Note: A = Primary Drinking Water MCL, Safe Drinking Water Act.  
B = Secondary Drinking Water MCL, Safe Drinking Water Act.  
C = Human Health Criteria, Clean Water Act.

Exceedance Values = Sample Concentration/Standard or Criteria concentration

DE/CC5/050.1



Table 3  
SUMMARY OF WATER SAMPLE RESULTS FROM THE GALENA SUBSITE  
FOR HEAVY METALS EXCEEDING AMBIENT WATER QUALITY  
CRITERIA FOR AQUATIC LIFE

CHRONIC CRITERIA

Metal	Criteria (µg/l)	Mean Metal Exceedance Values			
		Mine Shaft		Private Wells	
		Total	Dissolved	Total	Dissolved
Zinc	47	408	422	40	37
Lead	3.2	242	92	19.8	--
Cadmium	1.1	101	95	46	61.7
Silver	12	--	25.8 <sup>a</sup>	66.9	66.7 <sup>a</sup>
Mercury	0.012	26.8	15.3	25.4	23.3
Copper	12	30.6	15.0 <sup>a</sup>	3.0	2.2
Chromium (VI)	11	1.1 <sup>a</sup>	--	7.6	6.6 <sup>a</sup>
Nickel	160	--	--	1.7 <sup>a</sup>	1.8 <sup>a</sup>

<sup>a</sup>Single Sample.

ACUTE CRITERIA

Metal	Criteria (µg/l)	Mean Metal Exceedance Values			
		Mine Shaft		Private Well	
		Total	Dissolved	Total	Dissolved
Zinc	320	60	62	7.8	8.8
Cadmium	3.9	28.5	26.8	12.9	17.4
Copper	18	20.4	10. <sup>a</sup>	2.3	1.9
Lead	83	9.3	11.9	2.8 <sup>a</sup>	--
Iron	1,000	5.5	1.5	6.4	8.1
Chromium (VI)	16	--	--	5.1	4.6 <sup>a</sup>
Silver	4.1	--	--	2.0	2.0 <sup>a</sup>

<sup>a</sup>Single Sample.

Exceedance Values = Sample concentration/standard or criteria concentration.





Table 4  
CHEROKEE COUNTY--GALENA SUBSITE,  
COMPARISON OF GROUNDWATER QUALITY DATA WITH  
PRIMARY AND SECONDARY DRINKING WATER STANDARDS

DRINKING WATER STANDARDS

Metal	MCL ( $\mu\text{g/l}$ )	Sample Type	Exceedances Values		
			Number	Mean	Maximum
Cadmium	10	MT	14	11.1	26.0
		PT	17	6.5	18.0
		MD	11	10.4	20.0
		PD	10	9.2	18.0
Chromium VI	50	MT	0	--	--
		PT	3	1.6	2.4
		MD	0	--	--
		PD	1	1.5	1.5
Iron <sup>a</sup>	300	MT	13	12.7	40.0
		PT	36	12.9	60.0
		MD	3	4.0	6.0
		PD	36	12.7	60.0
Lead	50	MT	13	15.5	54.0
		PT	1	4.6	4.6
		MD	5	16.0	46.0
		PD	0	--	--
Manganese <sup>a</sup>	50	MT	15	4.9	8.2
		PT	28	5.1	24.0
		MD	11	5.1	7.2
		PD	23	5.7	28.0
Selenium	10	MT	0	--	--
		PT	1	1.1	1.1
		MD	0	--	--
		PD	2	1.4	1.6
Zinc <sup>a</sup>	5,000	MT	12	4.2	9.0
		PT	7	1.6	3.0
		MD	11	4.0	7.0
		PD	6	1.7	2.8

<sup>a</sup>Secondary standard.

Note: MCL - Maximum Contaminant Level.  
 MT - Mine shafts, total metals, 15 samples.  
 PT - Private wells, total metals, 129 samples.  
 MD - Mine shafts, dissolved metals, 15 samples.  
 PD - Private wells, dissolved metals, 110 samples.  
 Exceedance Values = Sample concentration/standard or  
 criteria concentration.



Table 5  
CHEROKEE COUNTY--GALENA SUBSITE,  
COMPARISON OF GROUNDWATER QUALITY DATA WITH  
WATER QUALITY CRITERIA

HUMAN HEALTH CRITERIA--CLEAN WATER ACT

Metal	Criteria (ug/l)	Sample Type	Exceedances Values		
			Number	Mean	Maximum
Cadmium	10	MT	14	11.1	26.0
		PT	17	6.5	18.0
		MD	11	10.4	20.0
		PD	10	9.2	18.0
Chromium (VI)	50	MT	0	--	--
		PT	3	1.6	2.4
		MD	0	--	--
		PD	1	1.5	1.5
Lead	50	MT	13	15.5	54.0
		PT	1	4.6	4.6
		MD	5	16.0	46.0
		PD	0	--	--
Nickel	15.4	MT	12	2.5	4.9
		PT	17	4.3	17.5
		MD	0	--	--
		PD	13	5.2	18.2
Selenium	10	MT	0	--	--
		PT	1	1.1	1.1
		MD	0	--	--
		PD	2	1.4	1.6
Silver	50	MT	0	--	--
		PT	3	2.0	2.7
		MD	0	--	--
		PD	1	2.0	2.0
Zinc	5,000	MT	12	4.2	9.0
		PT	7	1.6	3.0
		MD	11	4.0	7.0
		PD	6	1.7	2.8

Note: MT - Mine shafts, total metals, 15 samples.  
PT - Private wells, total metals, 129 samples.  
MD - Mine shafts, dissolved metals, 15 samples.  
PD - Private wells, dissolved metals, 110 samples.  
Exceedance Values = Sample concentration/standard or  
criteria concentration.



Table 6  
CHEROKEE COUNTY--GALENA SUBSITE, COMPARISON OF GROUNDWATER  
QUALITY DATA WITH WATER QUALITY CRITERIA

CHRONIC AMBIENT WATER QUALITY CRITERIA FOR AQUATIC LIFE

Metal	Criteria ( $\mu\text{g/l}$ )	Sample Type	Exceedances Values		
			Number	Mean	Maximum
Cadmium	1.1	MT	14	101	236
		PT	23	46	164
		MD	11	95	182
		PD	0	61.7	219
Chromium (VI)	11	MT	1	1.1 <sup>a</sup>	1.1 <sup>a</sup>
		PT	3	7.6	10.9
		MD	0	--	--
		PD	1	6.6 <sup>a</sup>	6.6 <sup>a</sup>
Copper	12	MT	4	30.6	41.6
		PT	47	3.0	10.8
		MD	1	15.0 <sup>a</sup>	15.0 <sup>a</sup>
		PD	25	2.2	5.4
Lead	3.2	MT	13	242	843
		PT	4	19.8	73
		MD	14	92	719
		PD	0	--	--
Mercury	0.012	MT	5	26.8	55.0
		PT	2	25.4	36.7
		MD	3	15.3	17.0
		PD	4	23.3	50.8
Nickel	160	MT	0	--	--
		PT	1	1.7 <sup>a</sup>	1.7 <sup>a</sup>
		MD	0	--	--
		PD	1	1.8 <sup>a</sup>	1.8 <sup>a</sup>
Silver	0.12	MT	0	--	--
		PT	3	66.9	91.7
		MD	1	25.8 <sup>a</sup>	25.8 <sup>a</sup>
		PD	1	66.7 <sup>a</sup>	66.7 <sup>a</sup>
Zinc	47	MT	15	408	940
		PT	89	40	319
		MD	11	422	763
		PD	70	37	298

<sup>a</sup>Single sample

Note: MT - Mine shafts, total metals, 15 samples.  
 PT - Private wells, total metals, 129 samples.  
 MD - Mine shafts, dissolved metals, 15 samples.  
 PD - Private wells, dissolved metals, 110 samples.  
 Exceedance Values = Sample concentration/standard or  
 criteria concentration.



Table 7  
CHEROKEE COUNTY--GALENA SUBSITE,  
COMPARISON OF GROUNDWATER QUALITY DATA WITH  
WATER QUALITY CRITERIA

ACUTE AMBIENT WATER QUALITY CRITERIA FOR AQUATIC LIFE

Metal	Criteria ( $\mu\text{g/l}$ )	Sample Type	Exceedances Values		
			Number	Mean	Maximum
Cadmium	3.9	MT	14	28.5	66.7
		PT	23	12.9	46.2
		MD	11	26.8	51.3
		PD	14	17.4	46.2
Chromium (VI)	16	MT	0	--	--
		PT	3	5.1	7.5
		MD	0	--	--
		PD	1	4.6 <sup>a</sup>	4.6 <sup>a</sup>
Copper	18	MT	4	20.4	27.7
		PT	37	2.3	7.2
		MD	1	10 <sup>a</sup>	10 <sup>a</sup>
		PD	15	1.9	3.3
Iron	1,000	MT	11	5.5	12
		PT	20	6.4	18
		MD	2	1.5	2
		PD	13	8.1	17
Lead	83	MT	13	9.3	32.5
		PT	1	2.8 <sup>a</sup>	2.8 <sup>a</sup>
		MD	4	11.9	27.7
		PD	0	--	--
Silver	4.1	MT	0	--	--
		PT	3	2.0	2.7
		MD	0	--	--
		PD	1	2.0 <sup>a</sup>	2.0 <sup>a</sup>
Zinc	320	MT	14	60	138
		PT	51	7.8	47
		MD	11	62	112
		PD	42	8.8	44

<sup>a</sup>Single sample

Note: MT - Mine shafts, total metals, 15 samples.  
PT - Private wells, total metals, 129 samples.  
MD - Mine shafts, dissolved metals, 15 samples.  
PD - Private wells, dissolved metals, 110 samples.  
Exceedance Values = Sample concentration/standard or  
criteria concentration.





Table 8  
COST ESTIMATES FOR THREE WATER TREATMENT ALTERNATIVES  
IRON MOUNTAIN MINE SITE, CALIFORNIA  
(MILLIONS OF DOLLARS)

	<u>Alternatives</u>		
	<u>Five Major Sources</u>	<u>Five Major Sources Plus Slickrock Creek</u>	<u>Five Major Sources Plus Boulder and Slickrock Creeks</u>
Water Flow Rate (gpm)	4,000	42,000	110,000
Costs			
Engineering	\$ 5.2	\$ 15.8	\$ 28.1
Construction	15.8	48.2	85.9
Operation and Maintenance (Present Worth)	18.0	20.0	22.0
RCRA Disposal-Sludge (Present Worth)	17.0	18.4	20.0
TOTAL	\$56.0	\$102.4	\$156.0

Notes: Order of magnitude level estimates (between +50 and -30 percent), including only major components.

Annual O&M costs ranged between \$1.9 and \$2.3 million.

Source: U.S. Environmental Protection Agency, 1985. Public Comment Feasibility Study. Iron Mountain Mine, Redding, California. EPA WA No. 48.9L170.0. August 2, 1985.

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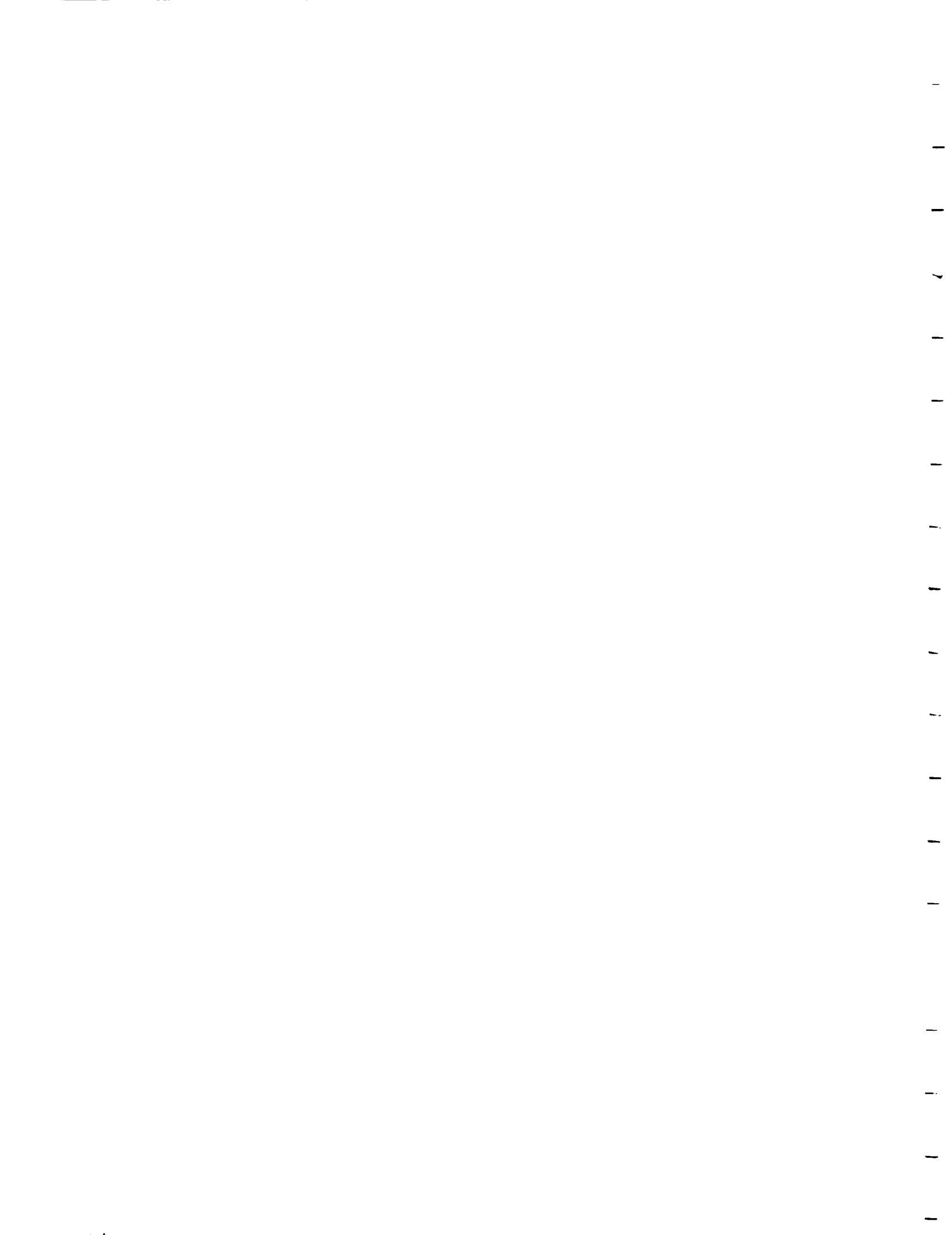
Table 9  
TREATMENT COSTS FOR ROUBIDOUX WATER SYSTEMS

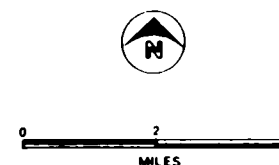
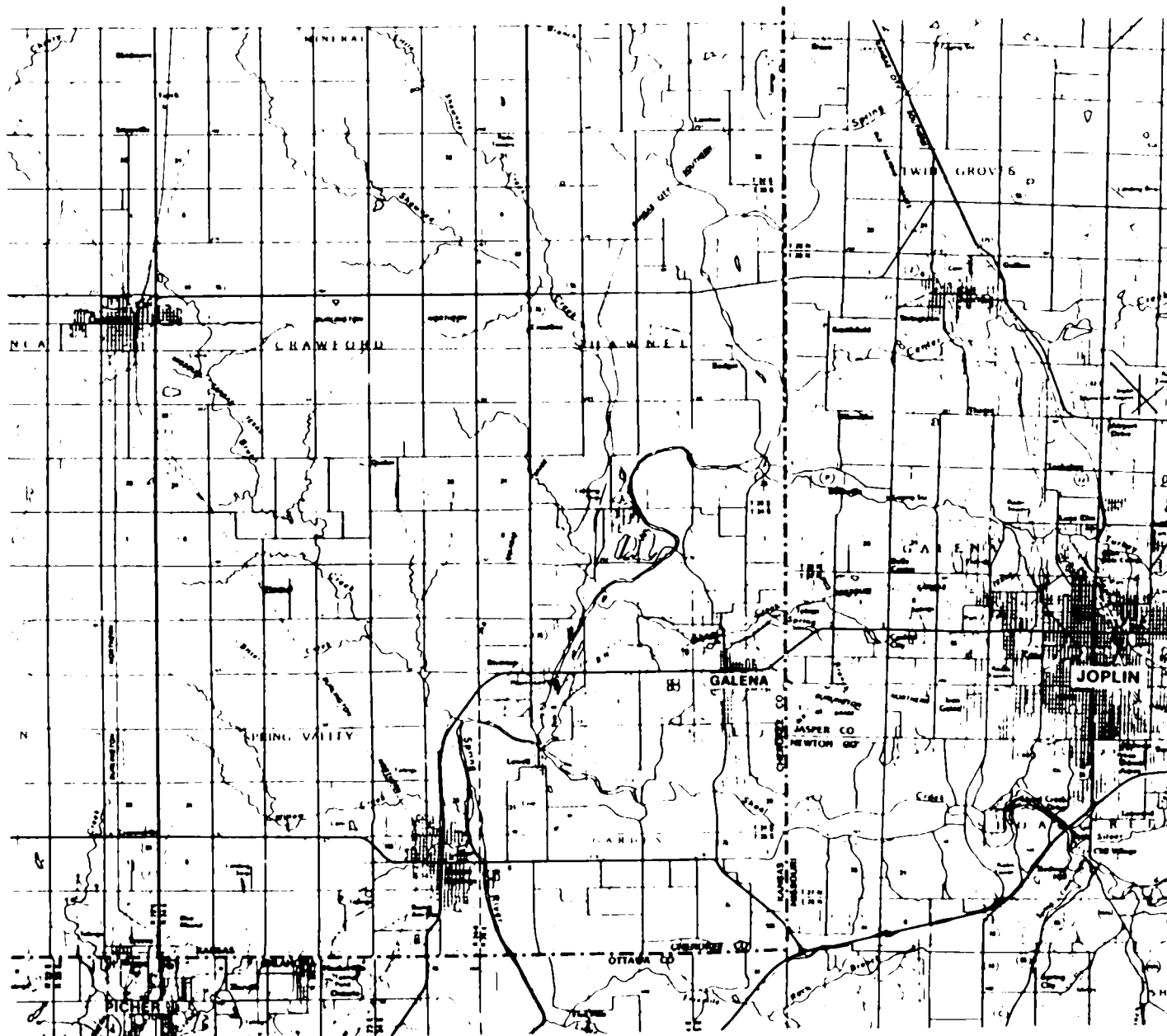
COUNTY: ESTIMATED COSTS FOR YEAR 2040 PROJECTED DEMANDS

<u>Entity</u>	<u>Average mgd</u>	<u>Plant Capacity (gpm)</u>	<u>Fixed Cost</u>	<u>Annual Cost</u>
<u>CRAIG</u>				
Bluejacket	0.030	20	\$ 175,000	\$ 40,000
RWD3	0.030	20	175,000	40,000
Welch	0.145	100	330,000	100,000
<u>DELAWARE</u>				
Bernice	0.436	300	\$ 650,000	\$ 180,000
Colcord	0.455	320	660,000	185,000
Kansas	0.130	90	320,000	90,000
Oakes	0.169	120	370,000	110,000
RWD1	0.075	50	240,000	65,000
<u>OTTAWA</u>				
Cardin	0.057	40	\$ 220,000	\$ 50,000
Commerce	0.414	290	640,000	175,000
Fairland	0.310	220	480,000	135,000
Miami/N.Miami	6.400	4,510	4,000,000	1,000,000
Pitcher	0.176	120	370,000	110,000
Quapaw	0.545	420	780,000	220,000
RWD 1 (Wyandotte)	0.073	50	240,000	65,000
RWD 2	0.076	50	240,000	65,000
RWD 3 (Peoria)	0.019	15	165,000	37,000
RWD 4	0.165	110	350,000	105,000
RWD 5	0.048	30	200,000	45,000
RWD 6	0.070	50	240,000	65,000
RWD 7	0.043	30	200,000	45,000
TOTAL	9.866		\$11,045,000	\$2,927,000

Source: Tar Creek Task Force, 1983. Tar Creek Feasibility Investigations: Task II.5.B.a-e, Treatment of Roubidoux Water Supplies. Prepared by Oklahoma State Department of Health, October 1983.

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**FIGURE 1**  
**TRI-STATE**  
**LOCATION MAP**  
**FOR THE GALENA**  
**KANSAS, JOPLIN,**  
**MISSOURI AND**  
**PICHER, OKLAHOMA**  
**AREA**  
 CHEROKEE CO. KANSAS  
 GALENA SUBSITE, PHASE I RI



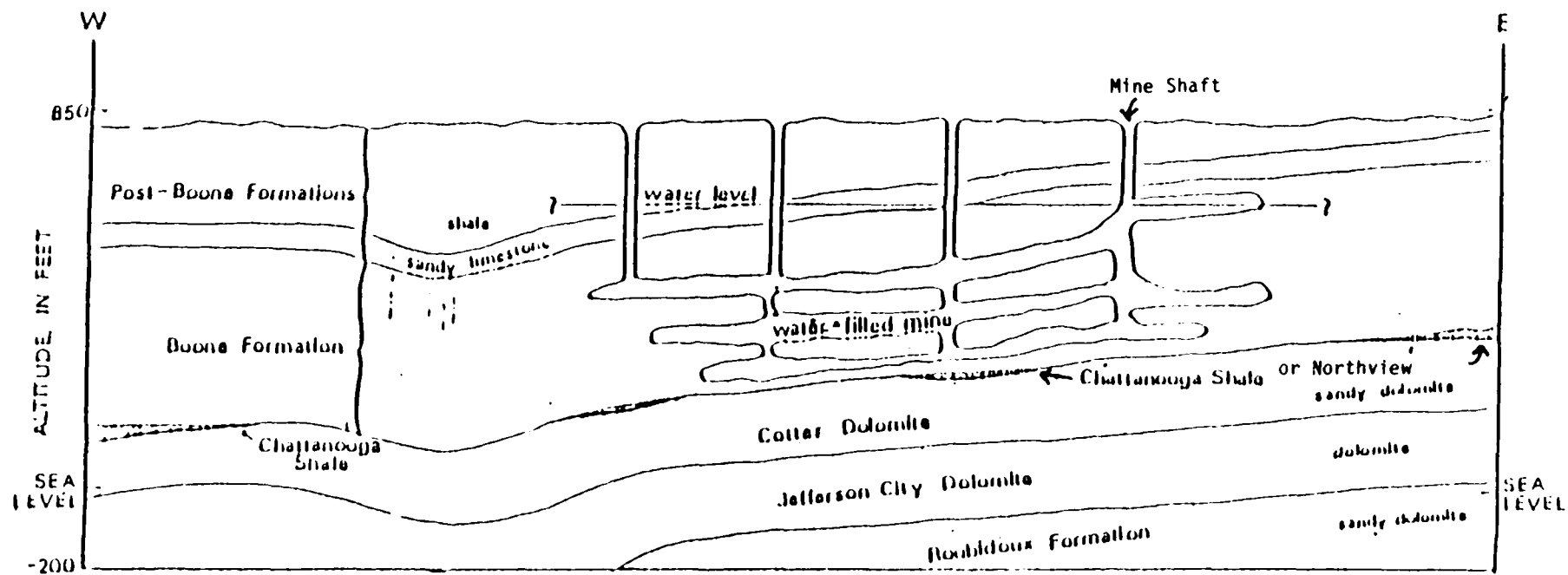
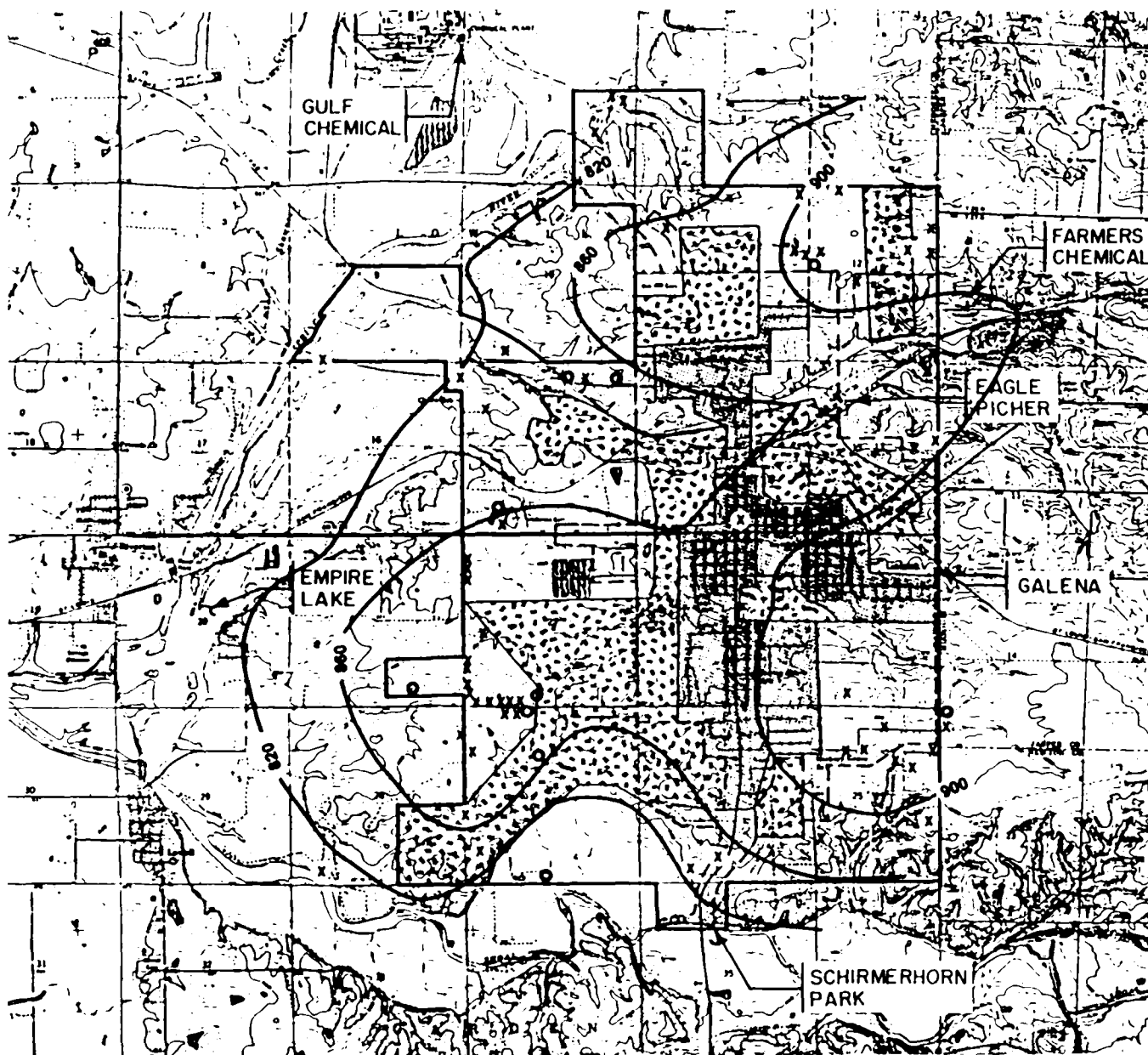


Figure 2.-Generalized geologic section showing relationship of rock formations to water-filled mines.







# LEGEND

- LIMITS OF WATER SUPPLY SURVEY
- AREA SERVICED BY THE GALENA MUNICIPAL WATER SUPPLY
- ▨ RESIDENTIAL/COMMERCIAL
- ▧ ABANDONED MINE LANDS
- AGRICULTURAL, RURAL RESIDENTIAL, AND WOODLAND
- 820 — ESTIMATED WATER ELEVATION (MSL) SHALLOW AQUIFER
- X PRIVATE WELLS WITH CADMIUM = 5 µg/l (ppb)
- O PRIVATE WELLS WITH CADMIUM > 5 µg/l (ppb) (1 spring)



0 1  
SCALE IN MILES

**FIGURE 3**  
**WATER SUPPLY SURVEY AREA**  
**AND GENERAL LAND USE**  
**WITHIN THE GALENA SUBSITE**  
 CHEROKEE CO. KANSAS  
 GALENA SUBSITE PHASE I RI

